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(54) Title: ENHANCED COEXISTENCE BEACON PROTOCOL (ECBP) FOR PRECISE INTERCELL SYNCHRONIZATION OF OVERLAPPING WIRELESS BASE STATIONS
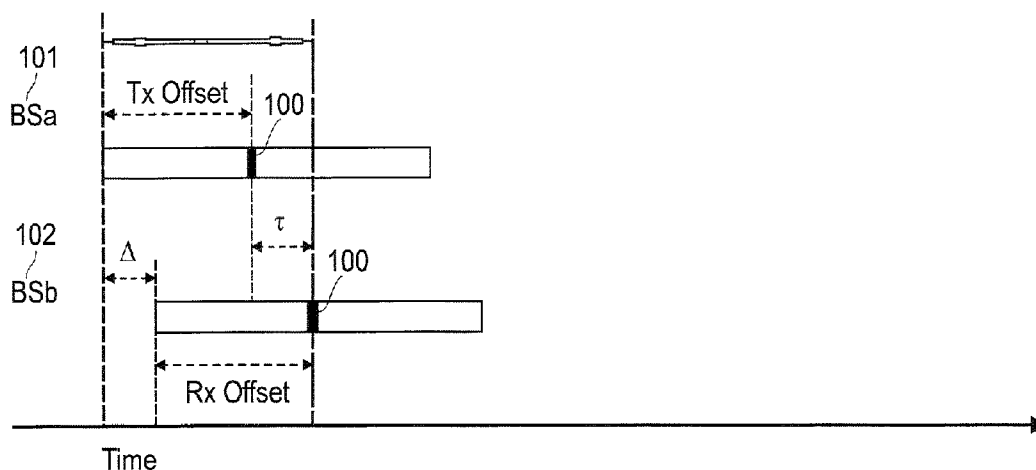
(57) Abstract: A method for synchronizing overlapping cells covered by different base stations include obtaining a propagation delay between a first base station and a second base station, scheduling by the first base station a selected one of first users located in a first cell covered by the first base station to transmit a first data packet which is a part of a transmission data frame, transmitting at the selected one the first users a transmission offset indicating the difference in a time domain between the beginning of the transmission data frame and the first data packet, in response to the reception of the first data packet, recording a reception offset at a selected one of second users located in a second cell covered by the second base station, the reception offset indicating the difference in time domain between the beginning of a reception data frame and the first data packet, transmitting at the selected one of the second users the reception offset to the second base station, calculating at the second base station a frame slide by adding the transmission offset and the propagation delay, and subtracting the reception offset, and synchronizing the first cell and the second cell based upon the calculated frame slide.

Description

ENHANCED COEXISTENCE BEACON PROTOCOL (ECBP) FOR PRECISE INTERCELL SYNCHRONIZATION OF OVERLAPPING WIRELESS BASE STATIONS

Technical Field

[1]   The present invention relates to a method for synchronizing overlapping cells over the air, and more particularly, to a method for precisely synchronizing overlapping cells by considering a propagation delay between a transmitter and a receiver.

Background Art

[2]   Time Division Duplex (TDD) applies time-division multiplexing to separate outward and return signals. Likewise, Frequency Division Duplex (TDD) applies frequency-division multiplexing to separate outward and return signals. For both FDD and TDD systems, it is recommended that all Base Stations (BSs) are time synchronized with respect to a common network timing signal. In an event of loss of the network timing signal, BSs should continue to operate and should automatically resynchronize to the network timing signal when the network timing signal is recovered.

[3]   Self-Coexistence occurs when multiple wireless systems of the same type exist at the same time (i.e., coexistence). In the case of IEEE 802.22, Self-Coexistence means co-existence of multiple overlapping IEEE 802.22 cells.

[4]   Precise network time synchronization is essential in general TDD systems, especially for Self-Coexistence situations. For example, when two units of Customer Premises Equipment, CPE_a and CPE_b are located in an overlapping cell area between two BSs BS_a and BS_b, if the two BSs are not synchronized, an uplink transmission between CPE_a and BS_a could destroy the downlink receiving between CPE_b and BS_b. In addition, precise network time synchronization is required to support a soft-handoff, the mobility management, inter cell communications and locating. Moreover, in an IEEE 802.22 system, for reliable spectrum sensing, it is desirable for neighboring cells to be quiet at the same time in order to establish a system-wide quiet period. The more precisely the neighboring cells synchronize, the less guard time is needed in order to align system-wide quite period or coexistence slots.

[5]   In IEEE 802.22, a method for synchronizing overlapping base stations over the air was disclosed. In this method, however, it was assumed that a propagation delay between two units of user equipment was negligible. This assumption, however, is not always legitimate. In fact, a 10 Km distance between two units of user equipment may result in about 33μsec of propagation delay, which is certainly not negligible. Therefore, it is important to take the propagation delay into account when performing

time synchronization.

Disclosure of Invention

Technical Problem

[6]   It is therefore an object of the present invention to provide an improved method and apparatus for data transmission.

[7]   It is another object to provide an improved method and apparatus for data transmission to achieve precise time synchronization, especially in intra-BS and in inter-BS communications.

[8]   It is still another object to provide a method and apparatus able to enhance self-coexistence and synchronization between overlapping base stations.

[9]   According to one aspect of the present invention, a method for synchronizing overlapping cells is provided, in which a first data packet and a transmission offset indicating the difference in a time domain between the beginning of a transmission data frame and the first data packet is transmitted at a first node. The first node is one of a first base station and a first user. The first user is located in a first cell covered by the first base station. In response to the reception of the first data packet, a reception offset indicating the difference in time domain between the beginning of a frame at the second base station and the first data packet is recorded at a second user located in a second cell covered by a second base station. Then the reception offset is transmitted at the second user to the second base station. A propagation delay between the first node and the second user is subsequently obtained. A frame slide is calculated at the second base station by adding the transmission offset and the propagation delay, and subtracting the reception offset. Finally, the first cell and the second cell is synchronized based upon the calculated frame slide.

[10]   The step of obtaining the propagation delay between the first node and the second user may include transmitting at the first node a data packet carrying information regarding the geographical location of the first node; in response to the reception of the data packet, calculating at the second user the propagation delay of the data packet based on the information regarding the location of the first node; and transmitting at the second user the propagation delay to the second base station.

[11]   When one of the first node and the second user does not have knowledge of geographical location of itself, the propagation delay between the first node and the second user may be calculated using round-trip communication without the information regarding the geographical location of the first node.

[12]   The step of obtaining the propagation delay between the first node and the second user may include generating and broadcasting a location database containing geographical location information of a plurality of users located within the first cell in as-

sociation with corresponding identifiers; transmitting via the first user a data packet carrying an identifier of the first user; in response to the reception of the data packet, retrieving at the second user the geographical location information of the first user from the location database in dependence upon the identifier; calculating at the second user a propagation delay in dependence upon the information regarding the location of the first user; and transmitting at the second user the propagation delay to the second base station.

[13]   The step of obtaining the propagation delay between the first node and the second user may include selecting by the first base station, a subset of first users for data transmission, with the first users being located in the first cell covered by the first base station; contenting by the subset of first users for transmitting a first reference data packet in a first time interval; transmitting by a certain one of the first users which won the contention, the first reference data packet; selecting by the second base station, a subset of second users for data reception, with the second users being located in the second cell covered by the second base station; in response to reception of the first reference data packet, contenting by the selected subset of second users for transmitting a second reference data packet in a second time interval; transmitting by a certain one of the second users which won the contention, the second reference data packet; calculating at the certain one of the first users a propagation delay between the certain one of the first users and the certain one of the second users; and transmitting at the certain one of the first users the propagation delay to the second base station. The certain one of the first users may transmit a third reference data packet. The selected one of the first users may compensate a processing delay of the first data packet when establishing cell synchronization.

[14]   The step of obtaining the propagation delay between the first node and the second user may include scheduling by the first base station the first user to transmit a first reference data packet; scheduling by the second base station the second user to receive the first reference data packet; scheduling by the second base station the second user to transmit a second reference data packet; and in response to reception of the second reference data packet, calculating at the first user a propagation delay of the reference data packet; transmitting at the first user the propagation delay to the second base station.

[15]   The first cell and the second cell may be overlapped.

[16]   According to another aspect of the present invention, a wireless communication system may be constructed with a first base station defining a first cell; a second base station defining a second cell. The second base station is synchronized with the first base station, by: scheduling by the first base station a selected one of a plurality of first users located within the first cell to transmit a first data packet which is a part of a

transmission data frame; transmitting at the selected one of the first users a transmission offset indicating the difference in a time domain between the beginning of the transmission data frame and the first data packet; in response to the reception of the first data packet, recording a reception offset at a selected one of a plurality of second users located within the second cell, the reception offset indicating the difference in time domain between the beginning of a frame at the second cell and the first data packet; transmitting at the selected one of the second users the reception offset to the second base station; obtaining a propagation delay between the selected one of the first users and the selected one of the second users; calculating at the second base station a frame slide by adding the transmission offset and the propagation delay, and subtracting the reception offset; and synchronizing the first cell and the second cell based upon the calculated frame slide.

[17]   When the one of the second users has knowledge of geographical location of itself, the one of the first users may transmit the second data packet carrying information regarding a distance between the one of the first users and the one of the second users.

[18]   According to still another aspect of the present invention, a method for synchronizing overlapping cells is provided, in which a first data packet with location information of a first node and a transmission offset indicating the difference in a time domain between the beginning of a transmission data frame and the first data packet in a first cell is transmitted by the first node. Upon receiving the data packet by a second node, the second node records a reception offset indicating the difference in time domain between the beginning of a frame and the first data packet in a second cell. Then a propagation delay between the first node and the second node is obtained based on the location information of the first node. Finally, a frame slide is calculated by the second node a frame slide as adding the transmission offset and the propagation delay, and subtracting the reception offset.

[19]   According to a further aspect of the present invention, a wireless communication system may be constructed with a first node constituting a first cell and a second node constituting a second cell. The second node is synchronized with the first node by: transmitting by the first node a first data packet with location information of the first node and a transmission offset indicating the difference in a time domain between the beginning of a transmission data frame and the first data packet in the first cell; receiving the data packet by the second node, and recording a reception offset indicating the difference in time domain between the beginning of a frame and the first data packet in the second cell; obtaining a propagation delay between the first node and the second node based on the location information of the first node; and calculating by the second node a frame slide as adding the transmission offset and the propagation delay, and subtracting the reception offset.

Brief Description of the Drawings

[20]   A more complete appreciation of the invention, and many of the attendant advantages thereof, will be readily apparent as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference symbols indicate the same or similar components, wherein:

[21]   FIG. 1 illustrates an example of typical cellular (including IEEE 802.22) deployment configuration;

[22]   FIG. 2 illustrates the structure of a CBP packet defined in IEEE 802.22;

[23]   FIG. 3 illustrates a method for synchronizing overlapping base stations, which does not consider the propagation delay between the CBP transmitter and the CBP receiver;

[24]   FIG. 4 illustrates establishment of synchronization between overlapping base stations;

[25]   FIG. 5 illustrates communication between two synchronized overlapping cells;

[26]   FIG. 6 illustrates a scenario for coexistence transmission;

[27]   FIG. 7 illustrates method for precisely synchronizing overlapping cells;

[28]   FIG. 8 illustrates another scenario for coexistence transmission;

[29]   FIG. 9 illustrates a method for synchronizing overlapping cells according to an embodiment of the present invention; and

[30]   FIG. 10 illustrates a specific example for synchronizing overlapping cells.

Best Mode for Carrying Out the Invention

[31]   Aspects, features, and advantages of the invention are readily apparent from the following detailed description, simply by illustrating a number of particular embodiments and implementations, including the best mode contemplated for carrying out the invention. The invention is also capable of other and different embodiments, and its several details can be modified in various obvious respects, all without departing from the spirit and scope of the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive. The invention is illustrated by way of example, and not by way of limitation, in the accompanying drawings.

[32]   This application incorporates by reference the IEEE 802.22: Draft Standard for Wireless Regional Area Networks Part 22.

[33]   It has been observed in §6.21.2 of IEEE 802.22 standards, that contrary to other IEEE 802 standards where self-coexistence issues are only considered after the specification essentially is finalized, the IEEE 802.22 takes the proactive approach (as specified in its Requirements Document) and mandates that the MAC should include self-coexistence protocols and algorithms as part of the initial standard conception and

definition. As depicted in FIG. 1, multiple 802.22 BSs and CPEs may operate in the same vicinity and, provided appropriate measures are taken at the air interface level, self-interference may render the 802.22 system useless. Even if directional antennas are used at the CPEs (although this may be implementation dependent), self-coexistence issues are not at all overcome. This is further aggravated by the fact that the range of 802.22 coverage can go up to 100 Km, and hence its interference range and impact on other collocated 802.22 cells is larger than in any other existing un-licensed technology.

[34]   FIG. 1 illustrates a scenario for coexistence transmission. Both Customer Premises Equipment_a (CPE_a) 105 and CPE_b 106 are located in an overlapping area between Cell_a 103 covered by Base Station_a (BS_a) 101 and Cell_b 104 covered by BS_b 102. CPE_a 105 transmits a Coexistence Beacon Protocol (CBP) packet in response to the direction of BS_a 101. CPE_b 106 receives the CBP packet and relays the message to its BS_b. The propagation delay between BS_a 101 and CPE_a 105 is τ1; the propagation delay between BS_b 102 and CPE_b 106 is τ2; and the propagation delay between CPE_a 105 and CPE_b 106 is τ3.

[35]   There are two types of beacon frames that can be used for intra-BS and inter-BS communication, and it is defined as the superframe header, which is transmitted by the BS in the beginning of every new superframe. The BS beacon is transmitted only by the BS. For inter-BS (alternatively, inter-WRAN) communication, CBP packets are employed and which can be transmitted by CPEs and BSs.

[36]   CBP packets are transmitted with the goal of improving self-coexistence amongst nearby IEEE 802.22 cells. These packets are transmitted under the control of the BS during an active self-coexistence window and share the same beacon MAC header. Since the goal of CBP packets is to improve self-coexistence, these CBP packets are sometimes refereed to as self-coexistence beacons.

[37]   Overall, the CBP packets provide information about the current cell as well as the CPE's traffic flows with its BS. Specifically, conveying the information about the traffic flows of a CPE with its BS is the responsibility of the Beacon IE, which is carried in the CBP packet payload and should appear in every CBP packet transmitted by a CPE.

[38]   CBP packets can carry in the payload one or more information elements. The CBP packets transmitted by CPEs should carry at least one beacon IE in their payload, since the beacon IE provides the basic information required to enable self-coexistence. CBP packets transmitted by the CPE may also carry a single DC/US Boundary IE. CBP packets transmitted by the BS should carry at least one DS/US Boundary IE, and may also carry one or more Beacon IE.

[39]   The Beacon IE provides necessary and sufficient information about the CPE's traffic

reservations with the BS (CPEs with no traffic reservations with the BS need not transmit CBP packets). At least one Beacon IE should be included in every CBP packet transmitted by CPEs. Stations (either CPEs or BSs) belonging to other IEEE 802.22 BSs and who receive a CBP packet, can then improve coexistence amongst BSs through a variety of mechanisms such as interference-free scheduling.

[40]   To cope up with the serious self-interference issues that may arise in a real deployment scenario, the CBP protocol should be employed. The CBP is a best-effort protocol based on coexistence beacon transmissions. Given the mechanism for synchronization of overlapping BSs and also the fact that, as noted below, CPEs do not continuously stay locked to a BS, successful delivery of coexistence beacon transmissions has high probability.

[41]   Several mechanisms may be implemented on top of CBP, such as the renter/offerer algorithm and etiquette for channel assignment.

[42]   The structure and transmission of a CBP packet is shown FIG. 2. As shown in FIG. 2, a CBP packet 100 includes a preamble 121, a SCH 122, and a CBP MAC Protocol Data Unit (PDU) 123. CBP packet 100 starts with a preamble 121 which should be common across all IEEE 802.22 networks, and which is different from the superframe preamble. After preamble 121, follows the SCH 122 transmission. By transmitting both SCH 121 (which contains information about the IEEE 802.22 cell) and the CBP MAC PDU 123 (which contains information about the CPE reservations with its BS), the transmitting CPE conveys all necessary information to allow for better self-coexistence.

[43]   In CBP, 802.22 entities (i.e., CPEs and BSs) are capable of transmitting beacons which provide its recipients enough information to achieve satisfactory and good coexistence amongst overlapping 802.22 cells. These beacons are intended for inter-cell communication and carry specific information about a CPE's cell of attachment and downstream/upstream bandwidth allocations with the BS.

[44]   In CMAC, coexistence beacons are scheduled through the use of Coexistence Interval Usage Code (IUC) (both Passive and Active) which can be specified in UpStream (US)-MAP and DownStream (DS)-MAP messages. When scheduling a coexistence beacon, the connection ID contained in the MAP IE indicates which CPEs should send the beacon within the specified scheduled time. This connection ID can be either unicast (e.g., a CPE's primary connection ID), multicast (i.e., a multicast management connection ID), or even the broadcast ID. In case of multicast, the BS can implement clustering algorithms that improve spectrum utilization and maximize the effectiveness of the coexistence beacons, as multiple CPEs would transmit a coexistence beacon during the same scheduled time. Irrespective of the type of connection ID, the CPE should always verify if the connection ID specified by the BS

includes itself or not. This will determine the CPE's behavior during the scheduled Co-existence IUC.

[45]   The Coexistence IUC defines a period of time where channel access is contention based. In other words, during this time CPEs should use the contention access mechanism (see 0) to gain access to the medium and transmit the coexistence beacon. The reason why a contention-based access mechanism is preferred for sending co-existence beacons is that it maximizes the spectrum usage. In the majority of cases, it is anticipated that the BS will not schedule just a single CPE to transmit beacons, but rather will attempt to improve coexistence by scheduling multiple CPEs to send beacons within the same time span (multicast management connections can be used for this purpose). Furthermore, when combined with the clustering algorithms, the ef-ficiency of this contention basing is maximized because, for the same Coexistence IUC, the BS will only schedule CPEs that do not belonging to the same physical cluster.

[46]   In order to maximize the probability that coexistence beacons are received from other collocated 802.22 cells, a CPE does not stay locked to the BS at all times during a frame. A CPE will only be locked to the BS whenever it is scheduled to receive/send data from/to the BS as is indicated through the US-MAP and DS-MAP messages. At all other times during the frame, the CPE will be listening to the medium and searching for a coexistence beacon. Thus, the probability of success and efficiency of the CBP is drastically increased. In case a CPE loses synchronization with BS while listening/ receiving a coexistence beacon, it should regain synchronization in the beginning following frame, which will cause few, if any, side effects.

[47]   Another mechanism that can be used by the BS to look out for CBP beacons is to schedule the Coexistence UIC in a Passive Mode. Essentially, the Passive Mode defines a time where the CPEs does not perform any transmission but simply listens to the medium while on the look out for CBP packets and, possibly, BS SCH beacons.

[48]   It is important to note that to increase the effectiveness of CBP, downstream/ upstream bandwidth allocations made by BS-to-CPEs in a certain frame should not change for a number of consecutive frames. This guarantees that the information carried in coexistence beacons is valid for at least a minimum duration of time, thus allowing enough time to the recipients of the coexistence beacon to implement self-interference mitigation mechanisms as are discussed below. Further, at any time when a BS must allocate bandwidth to a CPE, it should always seek to allocate this bandwidth based on the previous allocations, if any, to this CPE. That is, the BS should always allocate bandwidth to a CPE using approximately the same combination of slot and logical channel. This will reduce the number of coexistence beacons that need to be transmitted by this CPE, since its neighbors would already have the information

regarding the allocations as these have not been changed by the BS. Other optimizations are also possible to improve the efficiency of the CBP, and make the transmission of coexistence beacons less frequent.

[49]   Once a CPE receives coexistence beacons from other collocated CPEs belonging to different cells, it can use this information in many ways in order to improve coexistence. The first thing a CPE may want to do is to convey to the BS the received information. The BS, in turn, will implement so-called "interference-free" scheduling algorithm, which schedules the various upstream/downstream traffic from and to CPEs in such a way that these allocations do not intersect with the allocations of this CPE's interfering with other CPEs. Another use of this information is for bandwidth request purposes. In this case, the CPE may include constraint elements when requesting upstream bandwidth allocation to the BS, thus providing the information the BS would need to avoid allocating time for this CPE which interferes with other collocated CPEs.

[50]   Yet another alternative is for the CPE not to send anything to the BS. Here, the BS would have to specifically send a Traffic Constraint Request (TRC-REQ) message to the CPE requesting for any constraints it might have regarding allocation. Other uses besides these are also possible.

[51]   As it is discussed later, CBP packets are used for multiple purposes in CMAC such as establishing and keeping synchronization, as well as for self-coexistence. Therefore, the process carried out at the BS to decide when and in which mode (i.e., passive or active) to schedule the Self-Coexistence IUC is mostly implementation dependent, while it is recommended that this be done every frame during normal operation.

[52]   CMAC is capable, however, of providing the necessary information to assist the BS in this decision process. In this case, it is recommended using the CPE statistics report as the basis for triggering the execution of CBP. For example, a decision criterion may be defined such that if the Packet Error Rate (PER) experienced by one or more CPEs (clustering can be used here) exceeds a predetermined threshold value per CBP, this would trigger the BS to schedule a Coexistence IUC for at least the corresponding CPEs.

[53]   Another simpler strategy for the BS is to implement a pseudo-random process wherein self-coexistence windows are statically scheduled with a certain frequency, but the mode (i.e., whether passive and active) is pseudo-random. This process is denominated pseudo-random in the sense that it can take into account other statistics in the decision process, such as traffic pattern.

[54]   The key aspect that undermines possibly all existing solutions for coexistence in reservation-based wireless systems is the lack of synchronization amongst co-channel overlapping BSs. Synchronization is a hard problem to be solved, but the benefits gained from having reliable synchronization are so significant that it is worth pursuing.

[55]   Traditionally, synchronization amongst overlapping BS has been a tackled through the backhaul. This simplifies both the PHY and MAC design, but it has as one of its major drawbacks the fact that it relies on third parties. In the particular case of IEEE 802.22, another critical drawback includes the fact that this technology is going to employ license-exempt operation, and hence the existence of a common backbone amongst competing operators serving a given location is very unlikely and cannot be assumed. This is further aggravated by the much longer coverage ranges that are expected from IEEE 802.22 cells.

[56]   Since coexistence is key in IEEE 802.22, synchronization becomes very critical in order to allow the IEEE 802.22 system to operate at its peak performance. In the case of IEEE 802.22, synchronization is beneficial both in the case of incumbent protection as well as for self-coexistence. In case of incumbents protection, synchronization is beneficial as it allows the quiet periods of overlapping BS to be synchronized. This will further enhance the incumbent detection probability, which can otherwise be compromised if overlapping occurs randomly. In the case of self-coexistence, synchronization will make the self-coexistence mechanisms much more effective, and hence provide efficient sharing of radio resources by overlapping IEEE 802.22 cells.

[57]   A mandatory scheme that allows overlapping BS to synchronize by aligning their frames in time addresses the problem with an over-the-air approach, in the sense that the scheme does not rely on any sort of fixed backhaul infrastructure. This is not to say, however, that the scheme cannot operate over the backhaul.

[58]   For any synchronization scheme to be effective, some constraints should be imposed on the overall frame timings. In the specific case of CMAC, superframes should have the same and fixed length in terms of time, or at a minimum should be an integral multiple of each other. Individual frames within a superframe should also have the same and fixed size, and at a minimum should be an integral multiple of each other. This will facilitate not only in establishing synchronization amongst overlapping cells, but, most importantly, will maintain synchronization with very low overheads.

[59]   Assume that no GPS device is available to the IEEE 802.22 BSs. If such device is available, synchronization may be accomplished by imposing an additional requirement that BSs should only initiate superframes at specific points in time.

[60]   An IEEE 802.22 cell should actively seek for other overlapping IEEE 802.22 cells in order to establish synchronization, as well as provide a technique by which other collocated cells can find it. Besides the capability that a CPE must be scanning for beacons whenever the CPE is not transmitting or receiving, two other mechanisms should also be used for this purpose which will considerably increase the probability of a successful synchronization: self-coexistence quiet periods and self-coexistence windows in both passive and active modes.

[61]   Besides quiet periods for the detection of incumbents, the BS should also schedule quiet periods for the purpose of self-coexistence, and these are hereby called as self-coexistence quiet periods. Typically, however, these quiet periods need not be as frequent as those for the detection of incumbents, although the BS has complete freedom to choose their occurrence. In practice, self-coexistence quiet periods could be scheduled during low peak hours, such as overnight, without causing any major impact on the system performance and responsiveness. During this time, both CPEs and the BS will search for CBP or SCH packets transmitted by overlapping IEEE 802.22 terminals belonging to other IEEE 802.22 cells. Whenever a BS powers up, it should never schedule self-coexistence windows in active mode (i.e., CBP transmissions) before at least one self-coexistence quiet period. This is done to ensure that, with high probability, a new IEEE 802.22 cell should first synchronize with any other collocated IEEE 802.22 cell before announcing its existence through CBP packets.

[62]   Self-coexistence quiet periods should always be scheduled within the boundaries of a superframe, and should be scheduled in a random way to increase the probability that overlapping BSs successfully detect each other. The duration of a quiet period will typically be of one frame. The BS should randomly pick the frame number between [0, **FS-1**], while the superframe number should be derived from [0, **NSTQP**], where **NSTQP** is the Number of Superframes within an Incumbent Quiet Period. **NSIQP** can be easily derived from the **TTQP** field. By doing this, we are enforcing that the frequency of self-coexistence quiet periods should be the same as the incumbent quiet periods. Obviously, this can be dynamically changed by the BS if it can estimate an increment or decrement in the number of overlapping BSs (e.g., through PER statistics reported by CPEs or backhaul signaling).

[63]   Self-Coexistence windows should also be used for this purpose, and should always be scheduled by the BS at the end of the US subframe. The first key difference between self-coexistence quiet periods and self-coexistence windows is the time granularity. While the former will typically take at least an entire frame, the latter happens within part of a frame. The second, and probably most significant, difference is that during the self-coexistence quiet periods CPEs and the BS do not perform any type of transmission, but only sense the channel. During self-coexistence windows, however, CPEs can transmit CBP packets if so scheduled by the BS (in the case of self-coexistence in active mode). A decision processes can be used at the BS to determine whether to schedule a passive or active self-coexistence period.

[64]   For every CBP or SCH packet received, the BS and CPEs should record the frame offset when they were received. Accuracy in this recording is critical for a successful synchronization. FIG. 3 depicts the relationship between the Transmission Offset and Reception Offset fields for a frame of size FS (in units of symbols), wherein the

propagation delay between BS1 and BS2 is small enough to be negligible. The Transmission Offset is marked relative to the beginning of the (super) frame at the BS1, and the Reception Offset is marked relative to the beginning of the (super) frame at the BS2 in the FIG. 3. These fields are important for establishing synchronization between two overlapping cells.

[65]   In order for this fully distributed synchronization process to converge within an acceptable duration, a Convergence Rule should be employed by the BS before any synchronization attempt. The correct application of this convergence rule should guarantee network convergence in all scenarios. Mathematically speaking, BSi, responsible for cell i, should only attempt synchronization to BSj, responsible for a neighboring cell j, if and only if:

[66]   MathFigure 1
         [Math.1]

$$\left| \begin{array}{l} ((FS_i - Frame\_Number_i - 1) \times FDC_i + (FDC_i - Reception\_Offset)) - \\ ((FS_j - Frame\_Number_j - 1) \times FDC_j + (FDC_j - Transmission\_Offset)) \end{array} \right| \le \frac{FS_i \times FDC_i + GuardBand \times SymbolSize}{2}$$

[67]   where $Frame\_Number_i$ is the frame number in which the CBP packet was received, $Frame\_Number_j$ is the frame number in which the CBP packet was transmitted and should be -1 in the case of a SCH, $GuardBand$ is the guard band to accommodate for, for example, propagation delay, FDC is the frame duration code, and FS is the number frames per superframe.

[68]   Given the requirement that $FSi = FSj = FS$ and $FDCi = FDCj = FDC$, we can further simplify this equation to:

[69]   MathFigure 2
         [Math.2]

$$\left| \begin{array}{l} (Frame\_Number_j - Frame\_Number_i) \times FDC + \\ Transmission\_Offset - Reception\_Offset \end{array} \right| \le \frac{FS \times FDC + GuardBand \times SymbolSize}{2}$$

[70]   Therefore, BSi should apply this convergence rule to each and every synchronization alternative available. Only those that satisfy this rule can proceed to the next phase.

[71]   Even after the convergence rule is applied to all possible synchronization alternatives, although unlikely, multiple choices may still remain that satisfy the convergence rule. The BS should attempt synchronization with each overlapping BS, one at a time. Unless the BS realizes that it is already synchronized with the overlapping network corresponding to the selected packet (i.e., with Slide Amount equal to 0 or FS - see below -, or through bookkeeping), the BS should immediately construct and transmit a FSL-REQ message as a broadcast to all CPEs in the cell, and should not

schedule any additional active mode self-coexistence interval until the scheduled time of the frame slide.

[72]   In constructing the FSL-REQ message, the Slide Count and Slide Amount fields should be configured as depicted in FIG. 125. Slide Count should be equal to the number of frames right before the start of the superframe of the overlapping BSs, and Slide Amount will be equal to the number of slots to the start of the overlapping BS' superframe. More specifically, the Slide Amount field and Direction fields in the FSL-REQ message should be set according to the following rules:

[73]   MathFigure 3

[Math.3]

$$SlideAmount = \begin{cases} FDC - Transmission\_Offset + Reception\_Offset, & if\,(FDC - Transmission\_Offset + Reception\_Offset \leq \left\lceil \dfrac{FDC}{2} \right\rceil) & (Case\,1) \\ Transmission\_Offset - Reception\_Offset, & otherwise & (Case\,2) \end{cases}$$

[74]   MathFigure 4

[Math.4]

$$Direction = \begin{cases} 0\,(Right), & if\,(Case\,1) \\ 1\,(Left), & otherwise\,(Case\,2) \end{cases}$$

[75]   On the CPE side, it should report back to the BS on any received CBP or SCH packets, unless it receives a FSL-REQ message from the BS in the meantime in which case it should terminate the self-coexistence procedure and return to normal operation. Regardless of whether it was the BS itself who detected the CBP or SCH packets, or if these were received as a result of a CPE report, the BS should proceed in the same way as described above in attempting synchronization. The key difference at the BS is that the CPEs who received the same SCH and CBP packets will report different values for the Reception Offset due to the fact that they experience different propagation delays. In this case, it is up to the discretion of the BS to select one of the packets, as these refer to the same network. To cope up with the different propagation delays, which consists essentially of allowing guard bands in Equation (1) and Equation (2).

[76]   Whenever sliding the frame to the left or to the right, the BS always should adopt the same behavior. That is, at the scheduled slide time the BS should initiate transmission of a new superframe (shown in FIG. 4). So that the frame slide does not disrupt any data communication, the BS scheduler should take this slide into account when scheduling US and DS transmissions.

[77]   The frame slide operation may result in a partial frame as indicated in FIG. 4. It is up to the BS to use this partial frame as it sees fit. For example, the BS could use this time as a quiet period. Another possibility is that the scheduler at the BS has the capability to schedule data transmissions during this time, and so airtime is not wasted. Yet

another option would be to keep this partial frame as idle time, which may be a simple strategy whenever the partial frame size is only a few slots.

[78]   Once synchronization is accomplished, maintenance is a simpler process. Once the FSL-REQ message goes into effect and the frame is shifted, the BS should schedule self-coexistence windows with a certain periodicity and always at the end of the US subframe.

[79]   Confirmation and maintenance of synchronization is performed through periodic CBP packet transmissions and receptions during self-coexistence windows. Once the first CBP packet is successfully received from the overlapping cell, synchronization is completed and confirmed. At this point, the BS should continue to schedule self-coexistence windows, but now with the main purpose of better self-coexistence through the exchange of traffic constraints. Of course, a positive side effect of the transmission and reception of CBP packets is that the overlapping cells can more easily remain synchronized. This will, in effect, provide the most performance gains for all synchronized IEEE 802.22 cells. FIG. 5 shows an example of how two synchronized 802.22 cells communicate over the air through the self-coexistence window.

[80]   Given the large propagation delays in an IEEE 802.22 network, synchronization from the point of view of the BS does not mean exact synchronization for all CPEs. This is due to the different propagation delays experienced by different CPEs. To account for this disparity in propagation delays, and to accommodate the preamble transmission and the contention backoff interval, the BS should schedule self-coexistence windows with an appropriate guard band, which is recommended to be at least three slots. In this way, the BS can provide a guard band and take into account the worst scenario for the transmission/reception of at least one CBP packet.

[81]   If a frame slide in a cell is the result of a report from one or more CPEs, together with the BS, these CPEs should be responsible for keeping track of the syn-chronization. During the maintenance phase, the CPEs should periodically transmit/ receive CBP packets to/from the synchronized cell in order to confirm continued syn-chronization. During this time, the CPE should not report to the BS on each and every CBP packet received. Rather, it should restrict its control information exchange with the BS to only those control information exchanges that are needed for better self-coexistence and to implement "interference-free scheduling".

[82]   In a method of synchronization as shown in FIG. 6, CPE_a 105 transmits a CBP, which is contained in a superframe. In addition, CPE_a 105 marks a "transmission offset" (Tx offset) of the CBP packet relative to the beginning of the superframe in Cell_a 103. The information of the transmission offset can be delivered by the CPE_a 105 (or BS_a 101). The transmission offset may include the information in MAC header, or information elements, or Protocol Data Unit (PDU) of the CBP packet, or

predefined signal. The transmission offset can indicate the offset (in units of slots) relative to the start of the first slot of the PHY PDU (including preamble) where the current frame is transmitted. After detecting the CBP packet, CPE_b 106 marks a "reception offset" (Rx offset) relative to the beginning of the superframe in Cell_b 104. CPE_b 106 reports this event to BS_b 103. Given the following two assumptions: (1) both of the transmission offset and the reception offset are for cell wide; and (2) propagation delay between CPE_a 105 and CPE_b 106 is negligible, BS_b 102 knows the difference between the transmission offset and the reception offset, thus aligning the superframe timing in Cell_b with that of Cell_a. For the first assumption, even though the CBP packet is transmitted by CPE_a 105, CPE_a 105 already makes sure the transmission offset is relative to BS_a 101. Therefore, BS_b 102 can always assume this transmission offset is defined relative to BS_a 101. The same concept applies for the reception offset. Namely, although the reception offset is measured by CPE_b 106 and is reported to BS_b 102, BS_b 102 can always make sure that the reception offsetis defined relative to itself, because either BS_b 102 or CPE_b 106 could consider the propagation delay between them so that the final reception offset is relative to BS_b 102. This is typically achieved by the ranging process. In other words, no matter how the CBP packet is transmitted and received, both of the transmission offset and the reception offset are assumed to be relative to the corresponding base stations.

[83]   Another example method of synchronization of overlapping cells is shown in FIG. 7. As shown in FIG. 7, there is no CPE involved. BS_a 101 directly transmits a CBP packet 100 to BS_b 102. CBP packet 100 is transmitted by BS_a 101 at the transmission offset and is received by BS_b 102 after the propagation delay τ. BS_b 102 measured the reception offset. The sum of the transmission offset and the propagation delay τ equals to the sum of the reception offset and the frame slide Δ. Although the propagation delay between the CBP transmitter and the CBP receiver, i.e. τ, is very small in the FIG 3, the propagation delay τ is large enough and may not be negligible in this case. Without the knowledge of the propagation delay τ between the CBP transmitter and the CBP receiver, BS_b 102 cannot calculate the frame slide Δ, and thus BS_b 102 cannot synchronize its transmission with BS_a. Therefore, the syn-chronization accuracy is directly limited by this kind of propagation delay. In other words, the second assumption is not always legitimate. If the distance between the two base stations is 30 Km, the propagation delay could be about 100μsec. As another case, BS_b could pick up the CBP packet from CPE_a directly. In this case, the propagation delay could easily be tens of microseconds, e.g., 10 Km cell radius could incur 33μsec synchronization error.

[84]   Another scenario of coexistence transmission is illustrated in FIG. 8, where CPE_a

105 is located in an overlapping area between Cell_a 103 covered by BS_a 101 and Cell_b 104 covered by BS_b 102. CPE_a 105 transmits a CBP packet in response to the direction of BS_a 101. BS_b 102 receives the CBP packet. The propagation delay between BS_a 101 and CPE_a 105 is τ1, while the propagation delay between BS_b 102 and CPE_a 105 is τ2. Using the existing method, the synchronization error could easily be tens of microseconds. Therefore, BS_b 102 cannot synchronize its transmission with BS_a 101 without the knowledge of propagation delay τ2.

[85]   The present invention provides a method for precise network synchronization by considering propagation delay when transmitting the CBP packet.

[86]   When two base stations (BSs) synchronize with each other, the propagation delay betweens the two BSs has to be calculated and cancelled out. This could be done through provisioning, e.g., BSa and BSb could get the location of both of them from a central database. The alternative method is to include the location information of the transmitter in the CBP packet. The receiver should know its own location already.

[87]   When the transmitter for the CBP packet is a CPE, the receiver could be a CPE or a BS. Then the propagation delay might be addressed by transmit-feedback handshaking.

[88]   It should be mandatory to require a BS to know the locations of neighboring BSs in order to support cell synchronization over the air. This information could be acquired through provisioning during cell installation. But, there may be an issue if cells from different vendors are required to be synchronized, when the vendors do not want to share the location information.

[89]   The other solution would be to include the message of the location of a BS at each SCH transmitted by the BS, so that a neighboring BS can calculate and cancel out the propagation delay between the BS and the neighboring BS to achieve cell synchronization. A problem with this method is that each SCH has to carry the overhead with the message of location.

[90]   In any case of this invention, propagation delay is considered when synchronizing overlapping cells.

[91]   In an embodiment according to the present invention, the transmitter transmits a CBP packet carrying location information of the transmitter, so that the receiver can calculate and cancel out the propagation delay to achieve cell synchronization. The location information can be delivered by SCH (Superframe Control Header) which includes location configuration Information Element (IE), or by CBP which includes location IE. Then the receiver can report the calculated propagation delay to the BS which covers or services the receiver. Alternatively, the receiver may report the location information of the transmitter to the BS which covers or services the receiver, and the BS may calculate the propagation delay based on the location information. If the BS also needs to know location information of the receiver, then the receiver is

able to transmit the location information of both the receiver and the transmitter. This method requires the transmitters to have a location solution using, for example, the Global Positioning System (GPS).

[92]   If a location database is available, the transmitter ID, rather than the exact location could be included in the CBP message. Then the receiver can retrieve the location of the transmitter from the location database using the ID.

[93]   In addition, the overhead of including location information in CBP message could be cut short, given that the receiver knows the exact location of the receiver, and the receiver knows the transmitter is within a certain radius (e.g., the transmitter and the receiver is within 50Km from each other). In other words, only the least important bits may be enough for inferring the exact location of the transmitter.

[94]   In another embodiment according to the present invention, the transmitter measures inter-cell delays using two-way communication and carries the information regarding the propagation delays in the CBP packet. The inter-cell delay may be $\tau3$ in the scenario illustrated in FIG. 6, or $\tau2$ in the scenario illustrated in FIG. 8. In this method, a new transmission procedure is needed for measuring the inter-cell delay no matter the inter-cell delay occurs between two CPEs, or between a BS and a CPE. Basically, the measurement requires an immediate follow-up transmission in order to measure the propagation delay.

[95]   As illustrated in FIG. 9, CBP packets are scheduled by BSs through a Self-Coexistence window. The Self-Coexistence window defines a period of time where channel access is contention bases, in order to maximize spectrum usage. In other words, during this time, CPEs should use the contention access mechanism to gain access to the medium and transmit the CBP packet. First, BS_a selects some CPEs (e.g., CPE_a1, CPE_a2 and CPE_a3) for transmitting a CBP packet in a contention manner (e.g., with the contention window of [0 ~ 7]). That is, CPE_a1, CPE_a2 and CPE_a3 contend for the transmission of the CBP packet. Alternatively, BS_a may assign only one CPE (e.g., CPE_a1) to transmit the CBP packet. BS_b selects some CPEs (e.g., CPE_b1, CPE_b2 and CPE_b3) for receiving the CBP packet. Whoever has received the CBP packet should send a follow-up message (i.e., another CBP packet) again in a similar contention manner. In other words, CPE_b1, CPE_b2 and CPE_b3 contend for the transmission of the follow-up message. The original CBP transmitter receives the feedback (i.e., the follow-up message) and calculates the propagation delay between the transmitter and the receiver. As a result, precise cell synchronization is established. Optionally, the CPE_ai which won the contention for transmitting the first CBP packet may transmit another follow up message to the CPE_bi.

[96]   One example of this process is illustrated in FIG. 10, where BS_a selects CPE_a1,

CPE_a2 and CPE_a3 located in cell_a to content for transmitting a first CBP packet in contention window 201. As a result of the contention, CPE_a1 wins the contention and transmits a first CBP packet at time t_0. The packet reaches the CPE_b's (e.g., CPE_b1, CPE_b2 and CPE_b3) in cell_b after a certain propagation delay, shown as τ_3 in the figure, at slightly different time. Suppose at time t_1 CPE_b2 receives the packet. After receiving the first CBP packet, CPE_b1, CPE_b2 and CPE_b3 content for the transmission of a second CBP packet (i.e., follow up message) in contention window 202. As a result of the contention, CPE_b2 wins the contention and transmits the second CBP packet at time t_2. This packet reaches CPE_a1 after a certain propagation delay, shown again as τ_3 in the figure. That is, at time t_4, CPE_a1 receives the second CBP packet. Note that the other CPE_as in cell_a might also receive the second CBP packet, but they cannot use the second CBP packet for calculating the propagation delay because they did not transmit the first CBP packet. CPE_a1 calculates the propagation delay between CPE_a1 and CPE_b2; the resulted propagation delay is $(t_4 - t_0) / 2$. As a result, precise cell synchronization is accomplished. As an alternative embodiment, the first CBP transmitter, i.e., CPE_a1 may send another follow-up message, i.e., a third CBP packet at time t_5. Suppose CPE_b2 receives this third CBP packet at t_6. Then CPE_b2 could calculate the propagation delay between CPE_b2 and CPE_a1; the resulted propagation delay is $(t_6 - t_2) / 2$.

[97]   In addition, BSs and CPEs could have a certain processing delay in transmitting and receiving CBP and SCH packets. These kinds of delay should be compensated if they are substantial. Generally, they won't be in practice. Specifically, the propagation delay between CPE_a and CPE_b is calculated using the round-trip communication. At t_0 CPE_a transmits a packet, at t_1 CPE_b receives the packet, at t_2 CPE_b transmits another packet, at t_3 CPE_a receives the packet. After the process, CPE_a measures $t_3 - t_0$ The value of $t_2 - t_1$ is the processing delay at CPE_b. If the processing delay is negligible, then the value $t_3 - t_0$ is the round-trip propagation delay between CPE_a and CPE_b. The one-way propagation delay between CPE_a and CPE_b equals to the half of the round-trip propagation delay. Therefore, $t_2 - t_1$ affect the precision of the propagation delay, and thus the precision of the inter-BS synchronization. Generally speaking, this processing delay is negligible if we are talking about obtaining the precision of 25μs for inter-BS synch.

[98]   As described above, propagation delays need to be measured and reported in CBP messages for synchronizing overlapping cells. Intra-cell delay can be measured by the ranging process. That is, all the CPEs in a cell align their transmission by the co-ordination of the BS via the ranging process. In other words, the BS measures the propagation delay of each CPE relative to the BS. Therefore, in the scenario as shown in FIG. 8, τ_1 is known by regular 'ranging' process between BS_a 101 and CPE_a 105,

but, τ_2 is not known because CPE_a 105 is not associated with BS_b 102. Similarly, in the scenario as shown in FIG. 6, τ_1 and τ_2 are known, whereas τ_3 is not known.

[99]   As shown in the FIG. 7, the transmission offset is relative to BS_a 101, and the reception offset is relative to BS_b 102, even though the transmitter and receiver of the CPE packets might be CPEs. The reason is that the propagation delay between BSa and CPEa, BSb and CPEb are known, and are removed in the equations.

Claims

[1]   A method for synchronizing overlapping cells, the method comprising the steps
        of:
        transmitting at a first node a first data packet and a transmission offset indicating
        the difference in a time domain between the beginning of a transmission data
        frame and the first data packet, with the first node being one of a first base
        station and a first user, and the first user being located in a first cell covered by
        the first base station;
        in response to the reception of the first data packet, recording, at a second user
        located in a second cell covered by a second base station, a reception offset in-
        dicating the difference in time domain between the beginning of a frame at the
        second base station and the first data packet;
        transmitting at the second user the reception offset to the second base station;
        obtaining a propagation delay between the first node and the second user;
        calculating at the second base station a frame slide by adding the transmission
        offset and the propagation delay, and subtracting the reception offset; and
        synchronizing the first cell and the second cell based upon the calculated frame
        slide.

[2]   The method of claim 1, with the step of obtaining the propagation delay between
        the first node and the second user comprising:
        transmitting at the first node a data packet carrying information regarding the
        geographical location of the first node;
        in response to the reception of the data packet, calculating at the second user the
        propagation delay of the data packet based on the information regarding the
        location of the first node; and
        transmitting at the second user the propagation delay to the second base station.

[3]   The method of claim 2, comprising, when one of the first node and the second
        user does not have knowledge of geographical location of itself, the propagation
        delay between the first node and the second user being calculated using round-
        trip communication without the information regarding the geographical location
        of the first node.

[4]   The method of claim 1, with the step of obtaining the propagation delay between
        the first node and the second user comprising:
        generating and broadcasting a location database containing geographical location
        information of a plurality of users located within the first cell in association with
        corresponding identifiers;
        transmitting via the first user a data packet carrying an identifier of the first user;

in response to the reception of the data packet, retrieving at the second user the geographical location information of the first user from the location database in dependence upon the identifier;

calculating at the second user a propagation delay in dependence upon the information regarding the location of the first user; and

transmitting at the second user the propagation delay to the second base station.

[5]   The method of claim 1, with the step of obtaining the propagation delay between the first node and the second user comprising:

selecting by the first base station, a subset of first users for data transmission, with the first users being located in the first cell covered by the first base station;

contenting by the subset of first users for transmitting a first reference data packet in a first time interval;

transmitting by a certain one of the first users which won the contention, the first reference data packet;

selecting by the second base station, a subset of second users for data reception, with the second users being located in the second cell covered by the second base station;

in response to reception of the first reference data packet, contenting by the selected subset of second users for transmitting a second reference data packet in a second time interval;

transmitting by a certain one of the second users which won the contention, the second reference data packet;

calculating at said certain one of the first users a propagation delay between said certain one of the first users and said certain one of the second users; and

transmitting at said certain one of the first users the propagation delay to the second base station.

[6]   The method of claim 5, further comprising said certain one of the first users transmitting a third reference data packet.

[7]   The method of claim 5, further comprising said selected one of the first users compensating a processing delay of the first data packet when establishing cell synchronization.

[8]   The method of claim 1, with the step of obtaining the propagation delay between the first node and the second user comprising:

scheduling by the first base station the first user to transmit a first reference data packet;

scheduling by the second base station the second user to receive the first reference data packet;

scheduling by the second base station the second user to transmit a second

reference data packet; and

in response to reception of the second reference data packet, calculating at said the first user a propagation delay of the reference data packet;

transmitting at said the first user the propagation delay to the second base station.

[9]   The method of claim 8, further comprising said the first users transmitting a third reference data packet.

[10]   The method of claim 1, comprised of the first cell and the second cell being overlapped.

[11]   A wireless communication system, comprising:

a first base station defining a first cell;

a second base station defining a second cell;

with the second base station being synchronized with the first base station, by:

scheduling by the first base station a selected one of a plurality of first users located within the first cell to transmit a first data packet which is a part of a transmission data frame;

transmitting at said selected one of the first users a transmission offset indicating the difference in a time domain between the beginning of the transmission data frame and the first data packet;

in response to the reception of the first data packet, recording a reception offset at a selected one of a plurality of second users located within the second cell, the reception offset indicating the difference in time domain between the beginning of a frame at the second cell and the first data packet;

transmitting at said selected one of the second users the reception offset to the second base station;

obtaining a propagation delay between said the selected one of the first users and said the selected one of the second users;

calculating at the second base station a frame slide by adding the transmission offset and the propagation delay, and subtracting the reception offset; and

synchronizing the first cell and the second cell based upon the calculated frame slide.

[12]   The wireless communication system of claim 11, with the step of obtaining the propagation delay between said the selected one of the first users and said the selected one of the second users comprising:

transmitting at said the one of the first users located in the first cell a second data packet carrying information regarding the geographical location of said the one of the first users;

in response to the reception of the second data packet, calculating at said the one of the second users located in the second cell the propagation delay of the data

packet in dependence upon the information regarding the location of the transmitter; and

transmitting at said the one of the second users the propagation delay to the second base station.

[13]   The wireless communication system of claim 12, comprising, when said the one of the second users has knowledge of geographical location of itself, said the one of the first users transmitting the second data packet carrying information regarding a distance between said the one of the first users and said the one of the second users.

[14]   The wireless communication system of claim 11, with the step of obtaining the propagation delay between said the selected one of the first users and said the selected one of the second users comprising:

generating and broadcasting a location database containing geographical location information of a plurality of first users located within the first cell in association with corresponding identifiers;

transmitting via said the one of the first users a second data packet carrying an identifier of said the one of the first users;

in response to the reception of the second data packet, retrieving at said the one of the second users the geographical location information of said the one of the first users from the location database in dependence upon the identifier;

calculating at said the one of the second users a propagation delay in dependence upon the information regarding the location of said the one of the first users; and

transmitting at said the one of the second users the propagation delay to the second base station.

[15]   The wireless communication system of claim 11, with the step of obtaining the propagation delay between said the selected one of the first users and said the selected one of the second users comprising:

selecting by the first base station, a subset of first users for data transmission;

contenting by the subset of first users for transmitting a first reference data packet in a first time interval;

transmitting by a certain one of the first users which won the contention, the first reference data packet;

selecting by the second base station, a subset of second users for data reception;

in response to reception of the first reference data packet, contenting by the selected subset of second users for transmitting a second reference data packet in a second time interval;

transmitting by a certain one of the second users which won the contention, the second reference data packet;

calculating at said certain one of the first users a propagation delay between said certain one of the first users and said certain one of the second users; and transmitting at said certain one of the first users the propagation delay to the second base station.

[16]   The wireless communication system of claim 15, further comprising said certain one of the first users transmitting a third reference data packet.

[17]   The wireless communication system of claim 11, further comprising said selected one of the first users compensating a processing delay of the first data packet when establishing cell synchronization.

[18]   The wireless communication system of claim 11, with the step of obtaining the propagation delay between said the selected one of the first users and said the selected one of the second users comprising:

scheduling by the first base station the one of the first users to transmit a first reference data packet;

scheduling by the second base station the one of the second users to receive the first reference data packet;

scheduling by the second base station said the one of the second users to transmit a second reference data packet; and

in response to reception of the second reference data packet, calculating at said the one of the first users a propagation delay of the reference data packet;

transmitting at said the one of the first users the propagation delay to the second base station.

[19]   The wireless communication system of claim 18, further comprising said the one of the first users transmitting a third reference data packet.

[20]   The wireless communication system of claim 11, comprised of the first cell and the second cell being overlapped.
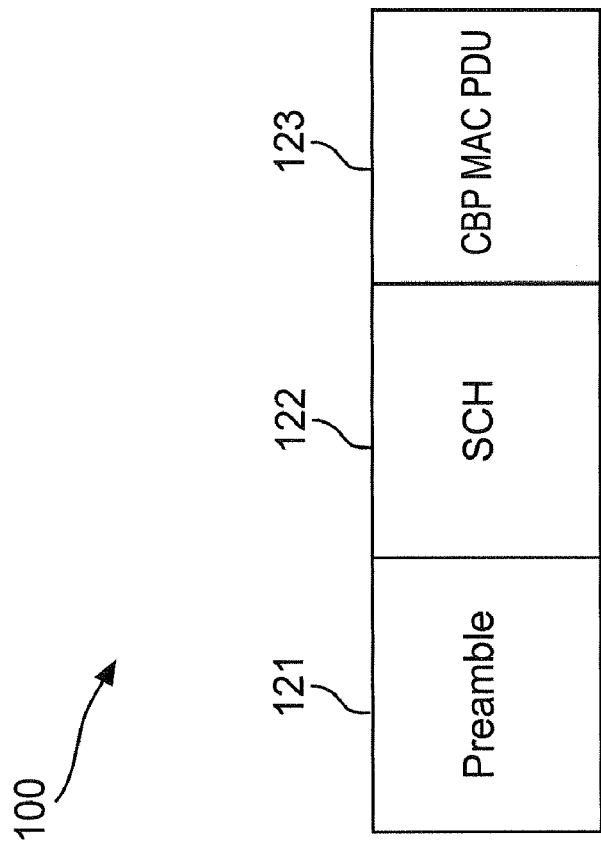
[21]   A method for synchronizing overlapping cells, the method comprising the steps of:

transmitting by a first node a first data packet with location information of the first node and a transmission offset indicating the difference in a time domain between the beginning of a transmission data frame and the first data packet in a first cell;

receiving the data packet by a second node, and recording a reception offset indicating the difference in time domain between the beginning of a frame and the first data packet in a second cell;

obtaining a propagation delay between the first node and the second node based on the location information of the first node; and

calculating by the second node a frame slide as adding the transmission offset

and the propagation delay, and subtracting the reception offset.

[22]   The method of claim 21, further comprising synchronizing the first cell and the second cell based upon the calculated frame slide.

[23]   The method of claim 21, with the first node being one of a first base station and a first user, the first user being located in the first cell covered by the first base station, the second node being one of a second base station and a second user, the second user beinglocated in the second cell covered by the second base station.

[24]   A wireless communication system, comprising:

a first node constituting a first cell;

a second node constituting a second cell;

with the second node is synchronized with the first node, by:

transmitting by the first node a first data packet with location information of the first node and a transmission offset indicating the difference in a time domain between the beginning of a transmission data frame and the first data packet in the first cell;

receiving the data packet by the second node, and recording a reception offset in-dicating the difference in time domain between the beginning of a frame and the first data packet in the second cell;

obtaining a propagation delay between the first node and the second node based on the location information of the first node; and

calculating by the second node a frame slide as adding the transmission offset and the propagation delay, and subtracting the reception offset.

[25]   The wireless communication system of claim 24, with the first node being one of a first base station and a first user, the first user being located in the first cell covered by the first base station, the second node being one of a second base station and a second user, the second user being located in the second cell covered by the second base station.
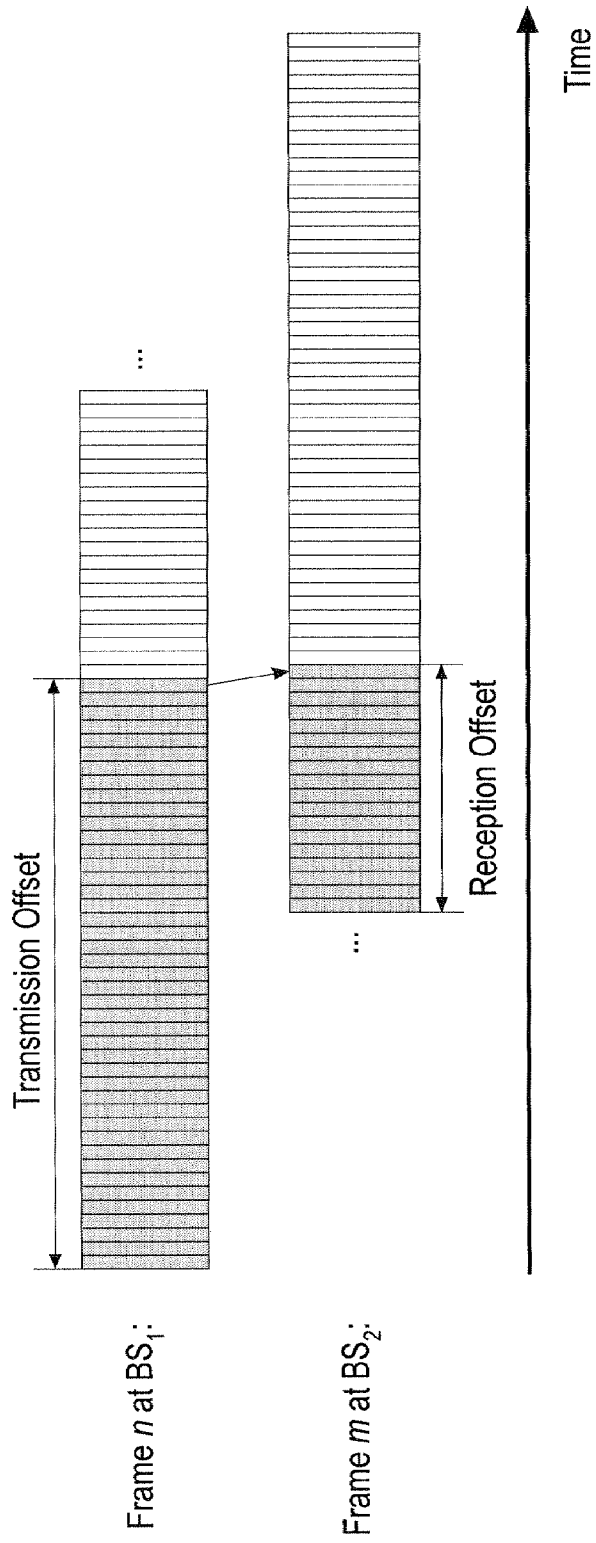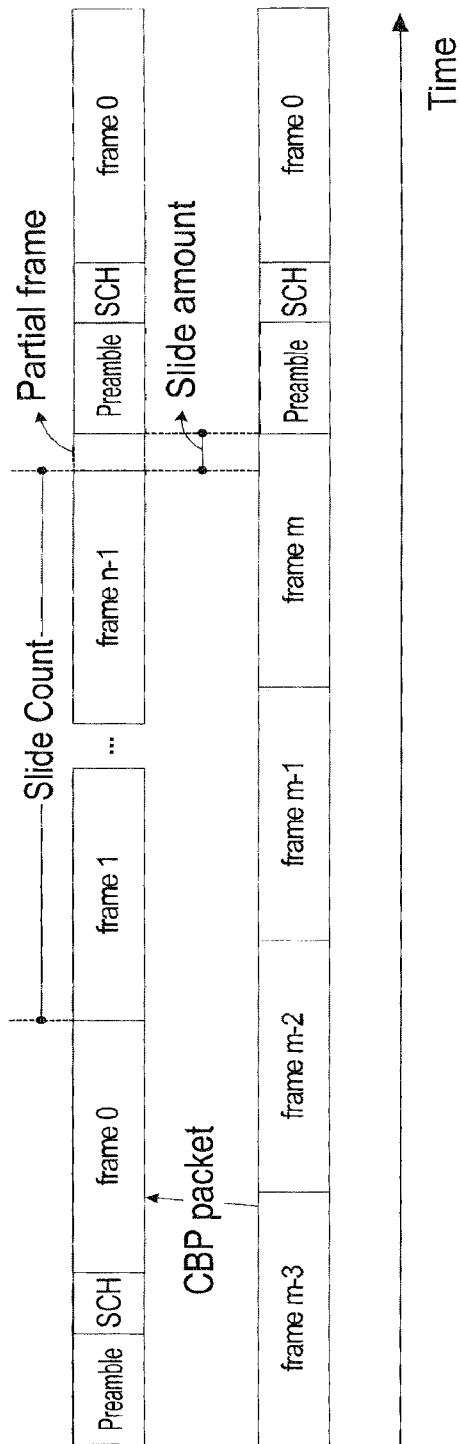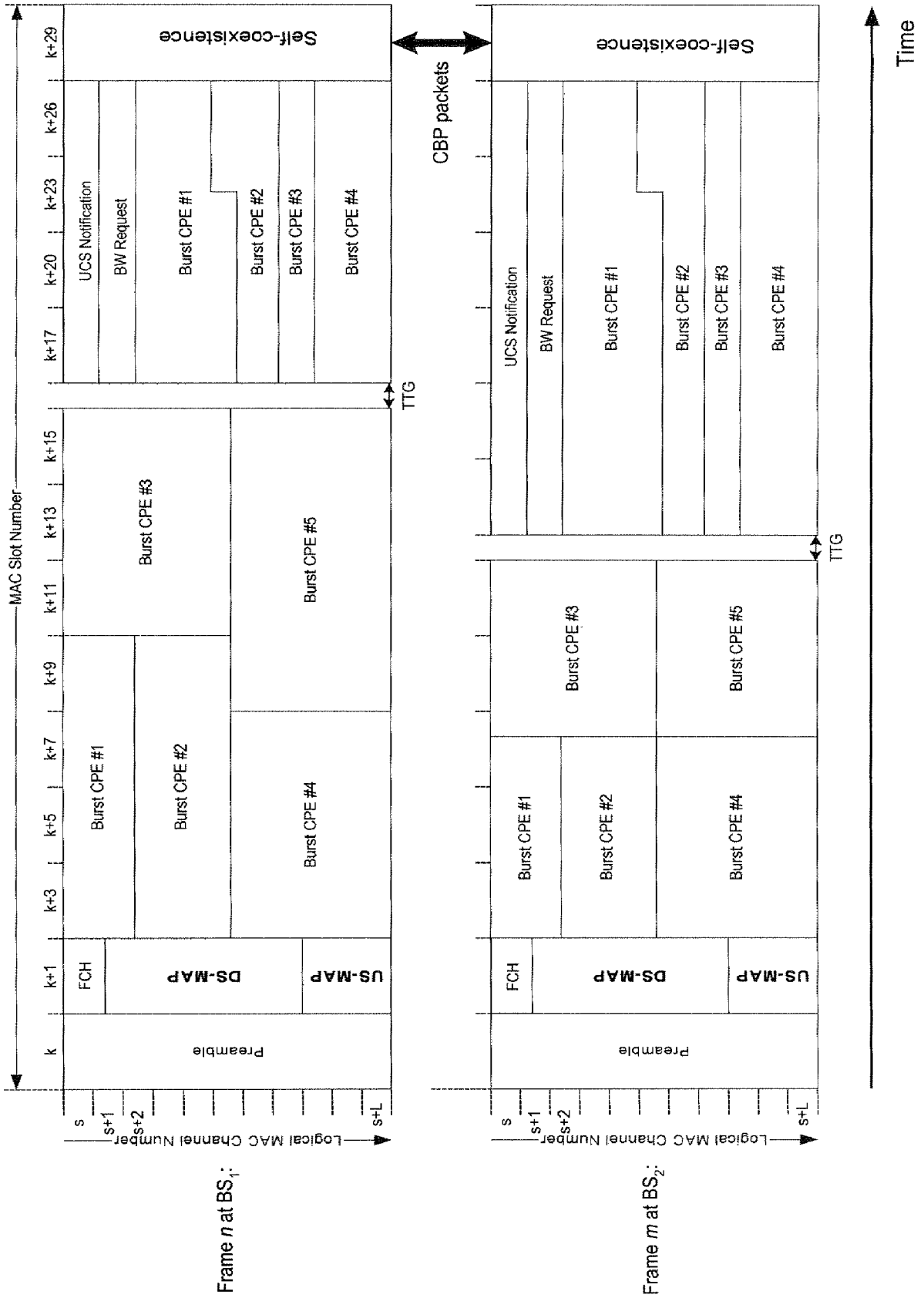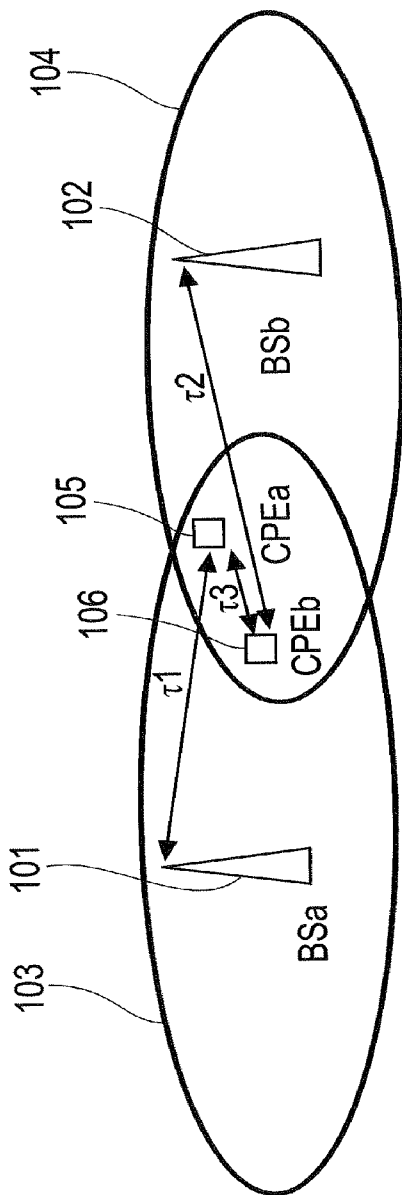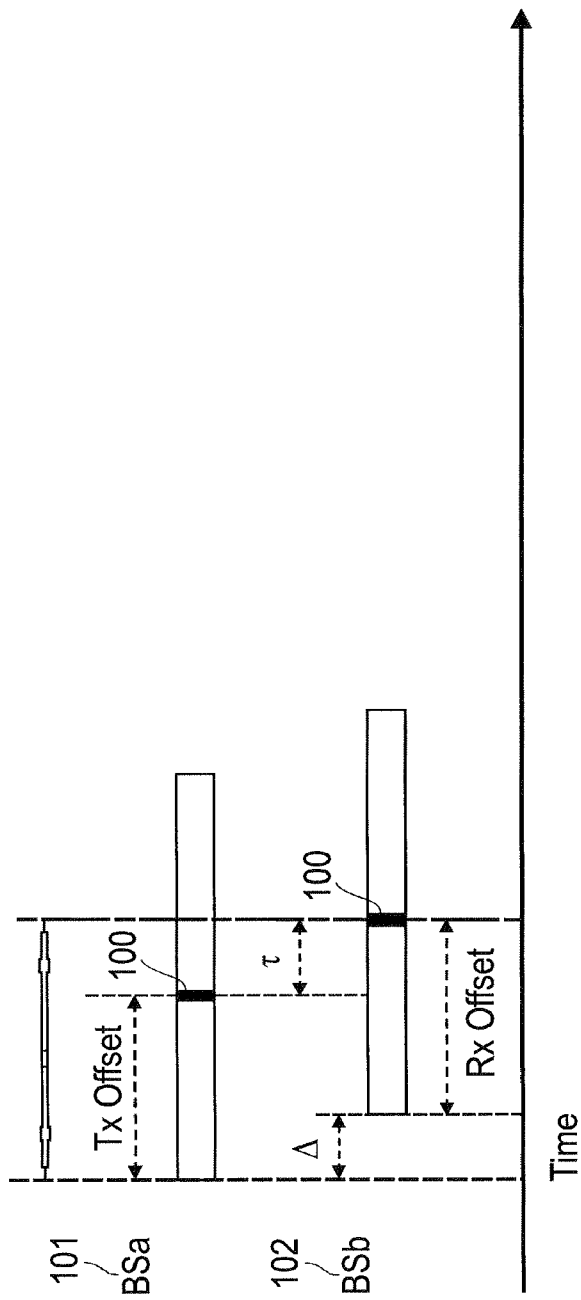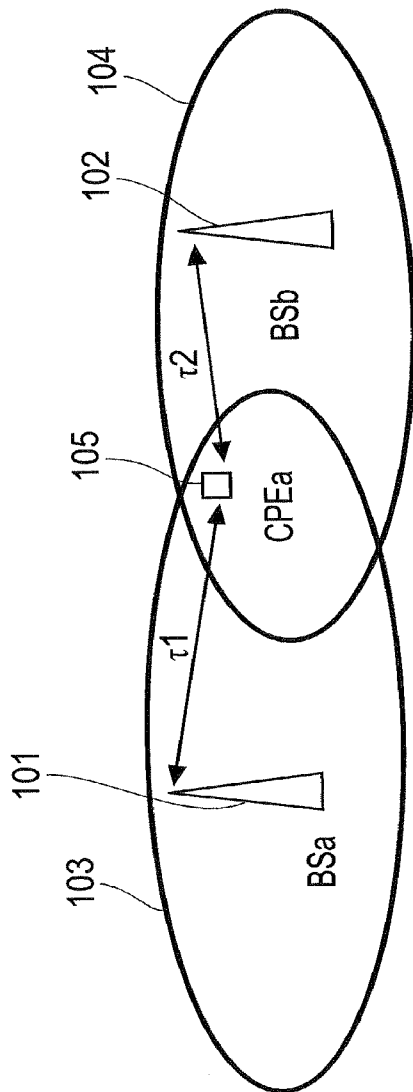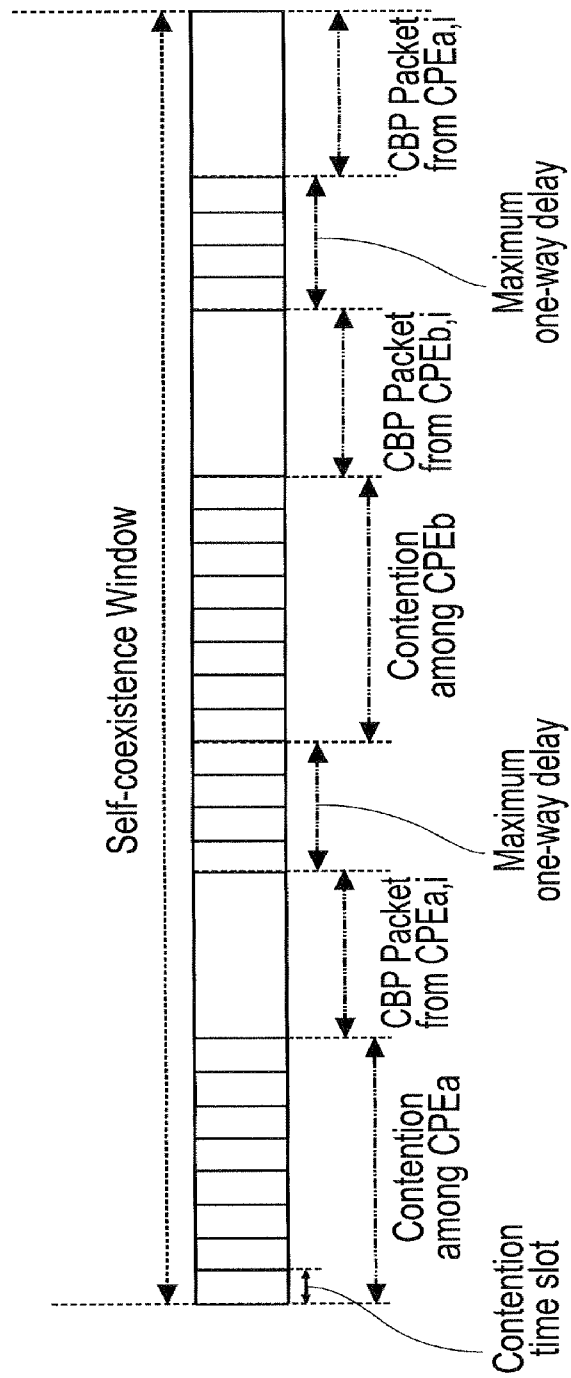
[Fig. 1]
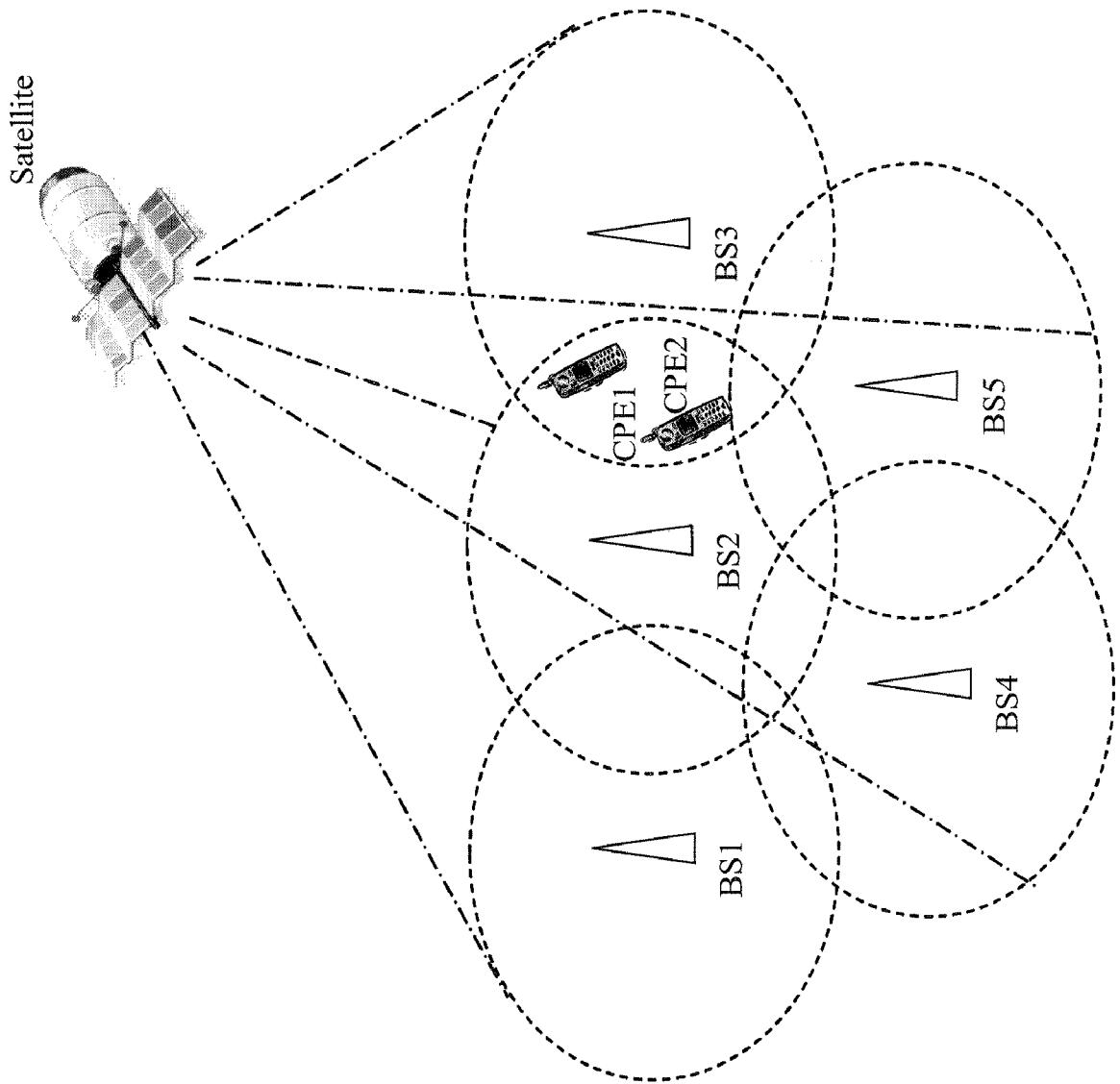
[Fig. 2]

[Fig. 3]

[Fig. 4]

[Fig. 5]

[Fig. 6]

[Fig. 7]

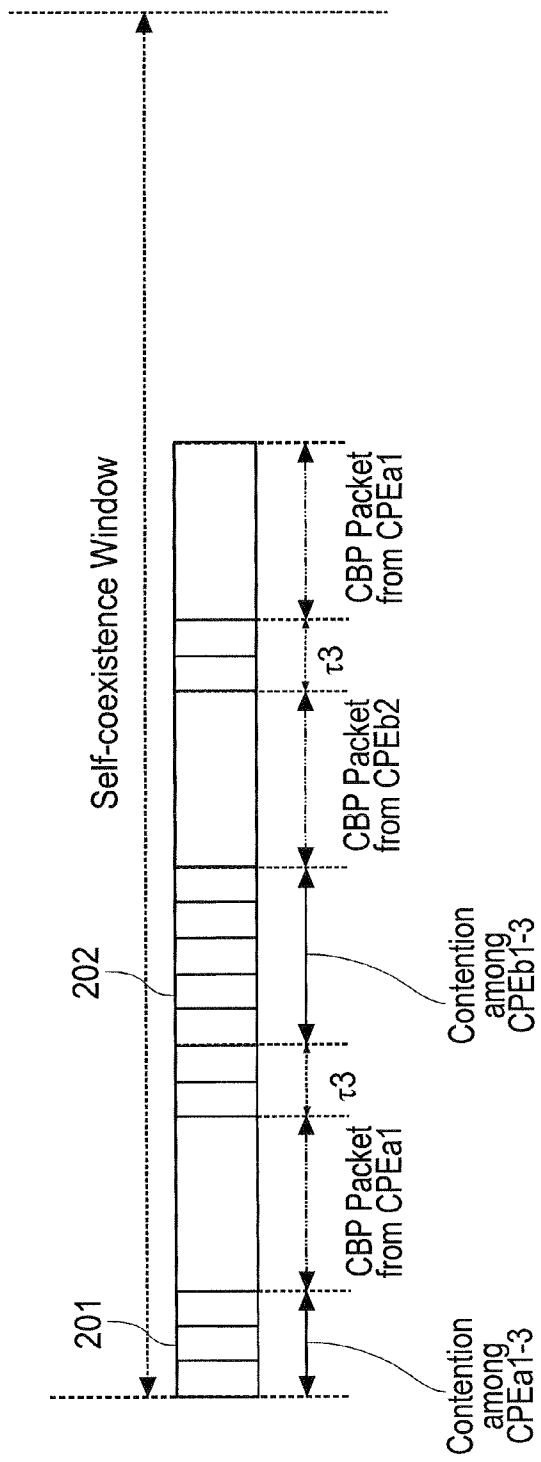[Fig. 8]

[Fig. 9]

[Fig. 10]
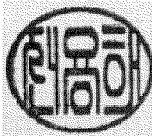
A. CLASSIFICATION OF SUBJECT MATTER

H04L 12/28(2006.01)i, H04B 7/26(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 8: H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EKIPASS(KIPO internal)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5864549 A (HONKASALO et al.) 26 Jan. 1999 See Column 3, Line 62 - Column 10, Line 42.	1-25
A	US 6359869 B1 (SONETAKA) 19 Mar. 2002 See Column 2, Line 22 - Column 6, Line 64.	1-25

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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